Aerospace Structures Information and Analysis Center

Crack Growth Testing

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Test specimens of TI-6-2-4-2 were tested in an effort to determine the basic properties of the material. The main property investigated was the crack growth rate, da/dn, relative to the size of the crack, a, over the fatigue life of the specimen. Yield zones at crack tips were also investigated on this material.

Specimens of Beta21S/SCS6, a titanium matrix composite, were also fatigue tested resulting in plots of crack growth rate, da/dn, against the stress concentration factor K.

Effort was also devoted to the development and installation of a new data system.

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FOREWORD

This report was prepared by the Aerospace Structures Information and Analysis Center (ASIAC), which is operated by CSA Engineering, Inc. under contract number F33615-90-C-3211 for the Flight Dynamics Directorate, Wright-Patterson Air Force Base, Ohio. The report presents the work performed under ASIAC Task No. T-59. The work was sponsored by the Structural Integrity Branch, Structures Division, Flight Dynamics Directorate, WPAFB, Ohio. The technical monitor for the task was Mr. Tony S. Lizza, Technical Manager of the Fatigue, Fracture and Reliability Section of the Structural Integrity Branch. The study was performed by Mr. Roger A. Post, CSA Engineering Inc.

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1. Introduction

The objective of this effort was to conduct research in the area of structural integrity at the subcomponent level. Much of the work done at the Fatigue and Fracture/Extreme Environment Test Facility. of the Fatigue, Fracture and Reliability Section, Structural Integrity Branch, Structures Division, Flight Dynamics Directorate, Wright Laboratory (WL/FIBEC), involves the testing of state of the art composites under cycled fatigue tests. Much of the data gathered from these tests has never been investigated before and is crucial to the development of new, lighter, higher strength structural components. This requires the continual development of new procedures in both analytical modeling and structural testing to help determine the reliability characteristics of common and exotic materials. The task included involvement in many different aspects of the laboratory environment, ranging from fatigue testing of specimens to the development of a new data acquisition system.

2. Fatigue Testing

Much of the work effort was focused on the actual testing of specimens. The main objective of the testing was to find a relationship between the growth rate of a crack and the crack size over the fatigue life of a specimen. The first step of the testing procedure was the precracking. Most specimens begin with a small notch, cut in the location of the desired crack growth. This tiny flaw causes the specimen to crack and fail at this location during the fatigue life. The specimens were tested by loading them in a test frame and applying a cycle of tensile and/or compressive loads. After a certain number of cycles the fatiguing was stopped and the crack length was measured. The crack length at a given number of cycles is the basic information needed to compute the crack growth rate, da/dn, and the stress concentration factor, K.

The first set of tests performed was the testing of TI-6-2-4-2 specimens to determine the basic material properties of the titanium metal matrix. These specimens were fatigue cycled with a constant load amplitude and max/min ratio. Different loads and ratios were used to produce a broad array of data. Initially the specimen was cycled a given number of cycles and the crack length was measured. After a initial set of data had been taken, the data was used in conjunction with the program **THRESCCT** to predict the number of cycles needed for the crack to grow a given distance, usually .015 inches. The specimen was then cycled the predicted number of cycles and the crack again measured. This process was repeated until failure. This procedure was used to assure a measurable amount of specimen growth over the number of cycles. This method produces dependable data since it customizes the measurements of the crack length to the increasing crack growth rate as the crack length increases. Data for this project is still being taken. The end result will hopefully produce a broad base of material fatigue data for the titanium metal matrix.

Overload data was also taken on the TI-6-2-4-2 specimens. An overload, two to three times greater than the cyclic load, was applied once to a pre-cracked specimen, producing a yield zone at the crack tip. The yield zone is an area where the specimen has been strained with a load significantly higher than the cyclic load. Since this area has already been strained with a stress higher than the cyclic load, the cyclic load will not affect the crack as much, producing a temporary retardation effect. After the yield zone was produced, the crack was

measured. The specimen was then cycled with the cyclic load until noticeable crack growth occurred. These tests showed that the larger the overload, the higher the number of cycles required to cause the crack to begin to grow again.

Another set of testing performed was of Beta 21S/SCS6, a titanium matrix composite. Testing of these specimens was performed in basically the same way as the preceding tests. The crack length was measured at intervals determined by the computer program **MATE**. Two electrodes were attached at opposite sides of the crack. At a given interval of cycles a voltage drop was applied across these electrodes. As the crack length increased, the electrical resistance of the specimen across the crack increased. This changing resistance was measured and calibrated to a initial crack length. The program was used to try to estimate the crack length as the specimen was being cycled. When the computer estimation reached a predetermined value the test was halted. The crack was then measured by hand, the crack resistance recalibrated to the present length and the test restarted. This cycle was continued until the specimen broke. This method of data acquisition produced a smoother curve of data than the first test because the data is taken more often as the crack begins to grow faster.

Even this method does not produce a smooth curve of da/dn vs. delta K, (figure 1). To obtain a smooth curve from the raw data several data reduction techniques were used. The curve of crack length, 'a', vs. number of cycles, 'N', was first smoothed using the program **Table Curve**. Data points were then picked for each .005 inches of crack growth and a corresponding stress concentration factor, 'K', and da/dn were computed. Figure 1 shows that this produced a smooth curve that corresponds to the test procedure. The horizontal gaps in the curve correspond to the areas where there was a increase in fatigue load. The vertical jumps correspond to large jumps in the crack growth rate in the raw data. This testing was done on several specimens with different load ratios, 'r'. These tests were a small portion of a large testing program to be done for the NASP program, but which have been discontinued due to the end of NASP funding.

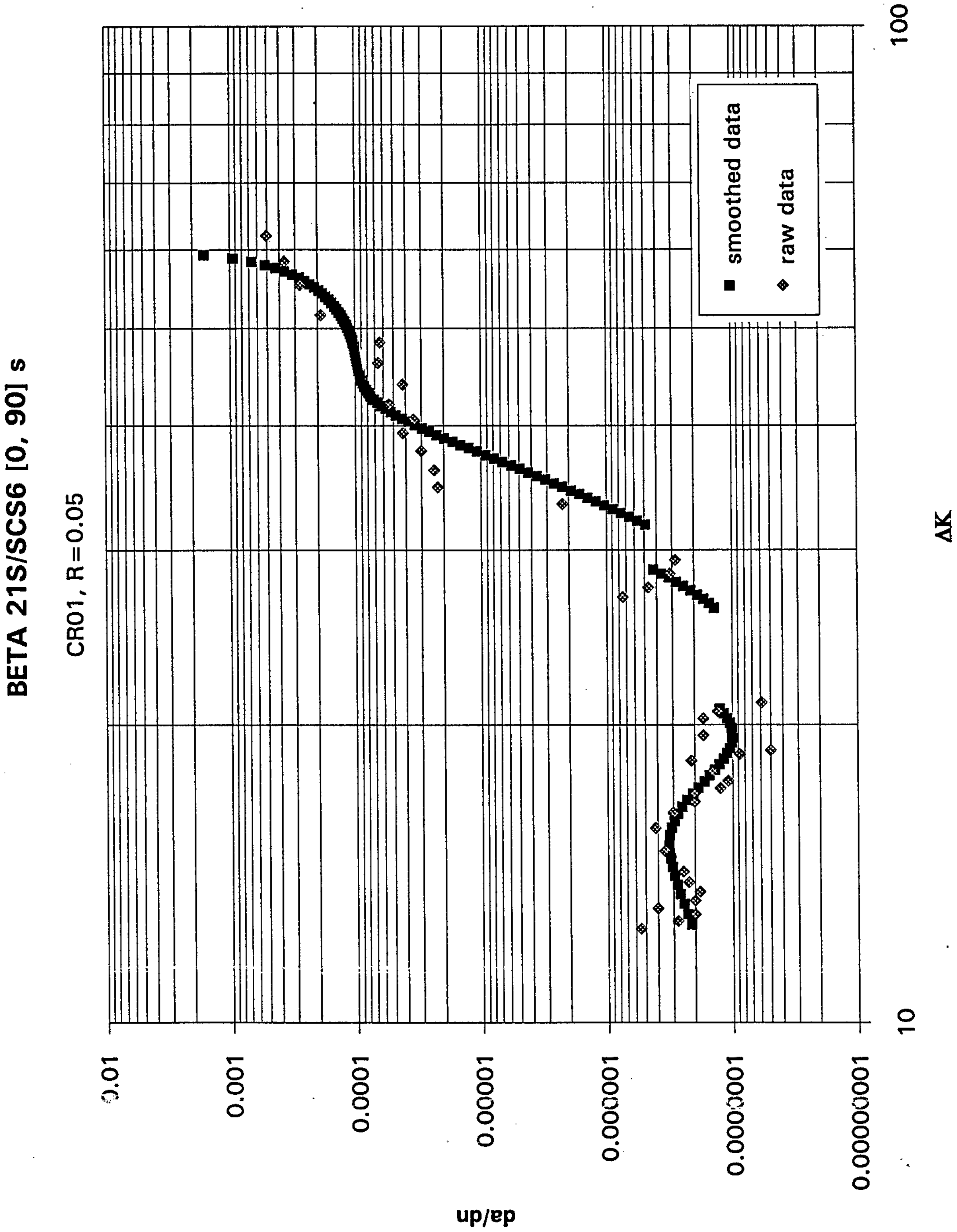

Figure 1. Crack Growth Rate as a Function of ΔK

3. Data System Development

Some time was spent on the development of a new data system for the Fatigue and Fracture/Extreme Environment Test Facility. The system records data from 15 different test-frames/computer-controllers simultaneously. Methods to check the reliability of the test-frame/computer-controller interface were investigated. The final solution to this problem was to send a signal from the controller to the data system, and a signal from the frame, independent of the controller, to the data system. The signals are then checked to see in the frame output is what the controller sent to the frame. The data system is designed to record all testing in progress. This data can be used at a later date to determine the reliability of a test. The data system also has the capability to monitor many channels of strain, stress, or any other feasible input. The system is presently in place and is awaiting the final computer programming needed to make it fully operational.

4. Summary

Test specimens of TI-6-2-4-2 were tested in an effort to determine the basic properties of the material. The main property investigated was the crack growth rate, da/dn, relative to the size of the crack, a, over the fatigue life of the specimen. Yield zones at crack tips were also investigated on this material.

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